SECRET

8 Feb 1956

TIME SCHEDULE [redacted] 25X1

	23 Jan-13 F[illegible] 3 weeks	Design transistorized audio amplifier to feed MINIFON.
	13 Feb-27 Feb 2 weeks	Design matching section from Microstrip horn to crystal.
	27 Feb-5Mar 1 week	Out for crystal conference.
X+1½	5 Mar-26 Mar 3 weeks	Cold test amplifiers, and compensate for temperature range.
X The Eng	26 Mar-9 Apr 2 weeks	Cold test batteries and design power pack.
	9 Apr-30 Apr 3 weeks	RF test antenna and detector unit to obtain optimum sensitivity and sensitivity calibration over the frequency range required.
X Mech Eng.	30 Apr-7 May 1 week	Design external switch.
X mixed, Shop Time	7 May-14 May 1 week	[redacted] 25X1
	14 May-28 May 2 weeks	Pot amplifiers and make final adjustments on demand system.
	28 May-11 June 2 weeks	Complete assembly of final model.
	11 June-18 June 1 week	Final test.

2nd wk May

Present estimated delivery dates for components of the project are as follows:

	Hewlett Packard test equipment	1 April (approx)
15	Haydon timing moter	1 Mar
	Miniature relay	27 Mar

SECRET

POWER REQUIREMENTS

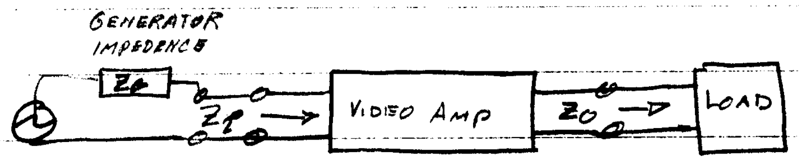
The record head of the MINIFON requires an input of about 40 volts peak to peak at an impedence of about 30,000 ohms.

With the 2,000 to 20,000 transformer which was included in the demand circuit (T_1) to feed the record head, a source capable of delivering about 10 volts peak to peak (3.5 Volts rms) into an impedence of about 2000 ohms is sufficient.

This source (approximately 5 milliwatts at 3.5 volts rms) is sufficient to activate the demand circuit.

Gain of Video-amp.
for optimum sensitivity

ACS
18 Jan 56



Assuming a matched input and output the power levels at input and output are related by:

(1) $$\frac{E_I^2}{Z_I} G_P = \frac{E_O^2}{Z_O} = P_L$$

E_O = output voltage
E_I = input "
Z_O = output load
Z_I = input impedance
G_P = power gain
P_L = load power

The input noise will be (again assuming a matched condition): $Z_G = Z_I$

(2) $$E_{IN}^2 = 4 \alpha k T \Delta f Z_I$$

k = Boltzmans const (1.374×10^{-23} watts/°K, cycle)

T = degrees Kelvin
Δf = Bandwidth cps
α = Noise ratio
(noise factor = $10 \log_{10} \alpha$)

from (1) the minimum detectable signal will be:

(3). $E_{i\,min} = \sqrt{\frac{P_L}{G_p} Z_i}$

So from (2) and (3) the ratio of the minimum detectable signal to the noise will be:

(4). $\frac{E_{i\,min}}{E_{in}} = \sqrt{\frac{P_L}{G_p \cdot 4\alpha KT\Delta f}}$

the power required to drive the 2N57 transistor is about $\frac{1}{2}$ mw, and Gp for the transistorized video amplifier is about 60 db or 10^6.

If $\alpha \simeq 10$ and $T = 300°K$, $\Delta f = 10^6$ cps

then $\frac{E_{i\,min}}{E_{in}} \simeq 1.7 \times 10^2$

~~this is about right.~~ Actually if the bandwidth of the video amplifier is no larger than 10^6 cps and α is no larger than 10, the gain (G_p) should be about 80 db. for an $E_{i\,min}/E_{in}$ of about 10.

An estimate of the noise generated in Microwave crystals
(reference Crystal Rectifiers, Torrey & Whitmer - MIT Lab series #15.
pp 344-349 and p. 432

In the absence of dc. bias on the crystal the noise is almost entirely Johnson noise:

Thus $P_n = 4KT\Delta f$

in our case Δf is about 1.5 MC

$$4KT\Delta f = 4 \times 4 \times 10^{-21} \times 1.5 \times 10^{6}$$
$$= 2.4 \times 10^{-14} \text{ watts}$$
$$= 2.4 \times 10^{-11} \text{ mw}$$

Thus about 110 db of gain is desired to raise the power level to about 2 mw. from a signal to noise ratio of 1.
(This noise is about 10 db above the noise to be expected from a transistor with a frequency ratio of about 250)

RCS 23 Jan 56

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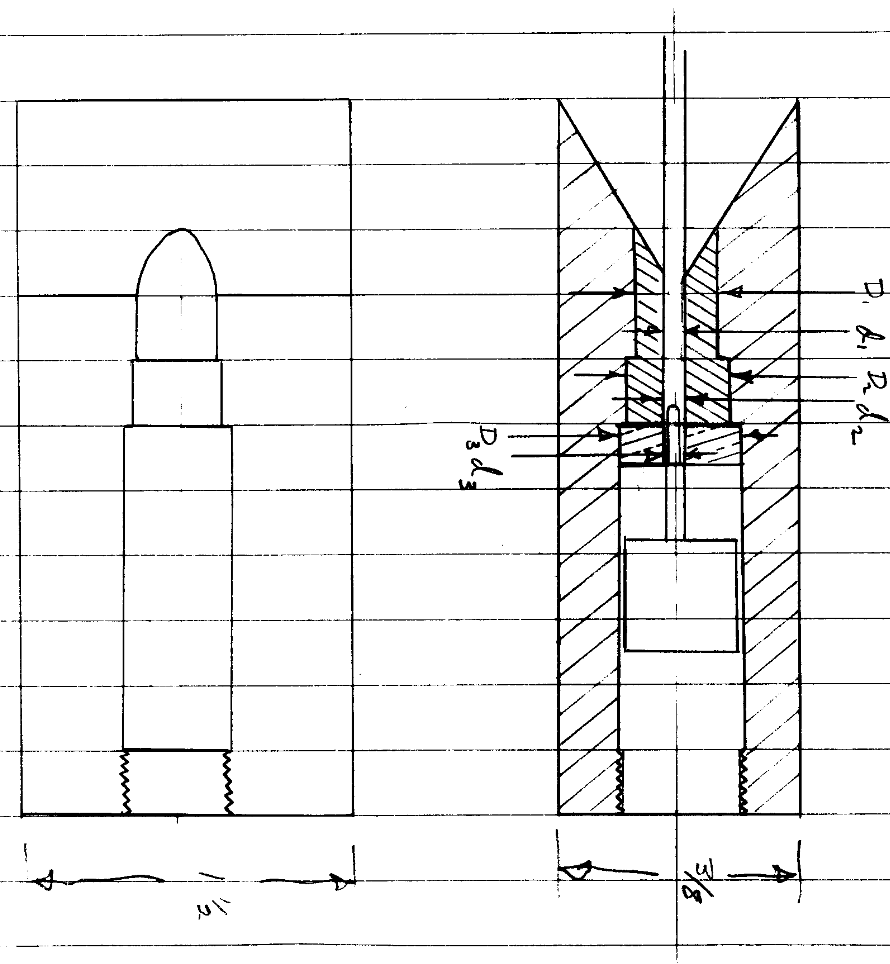
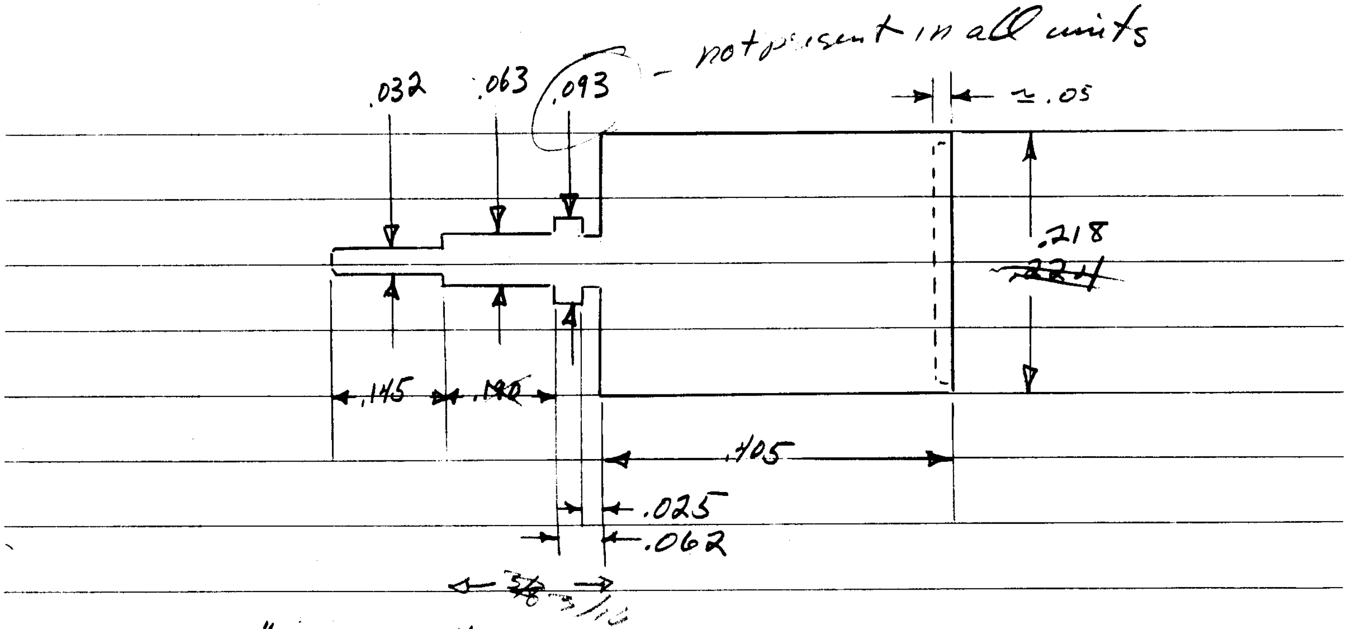
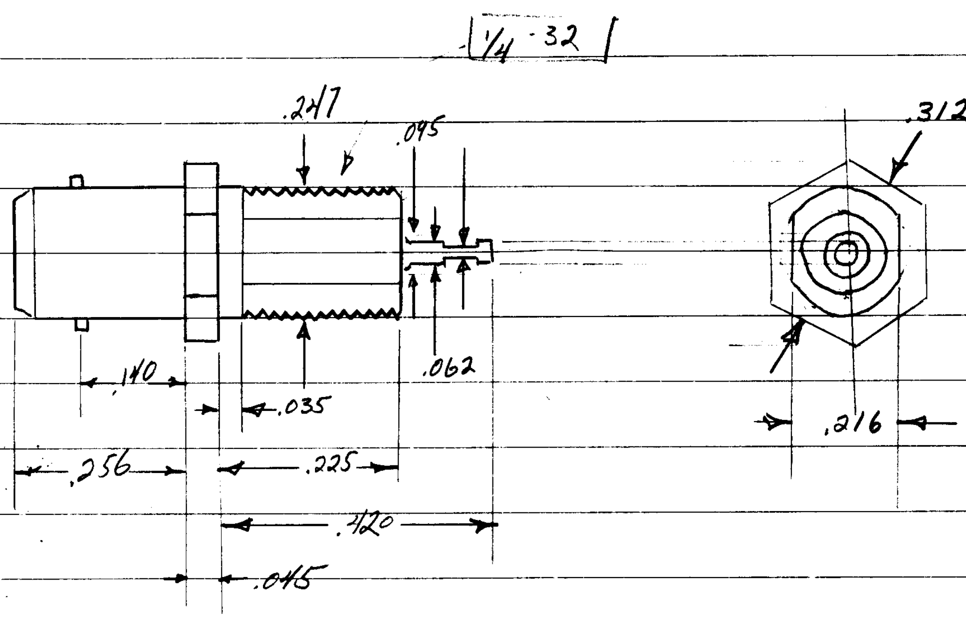


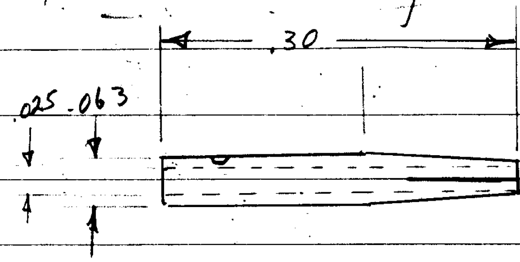
1/2"
3/8"
D1 d1 D2 d2
D3 d3



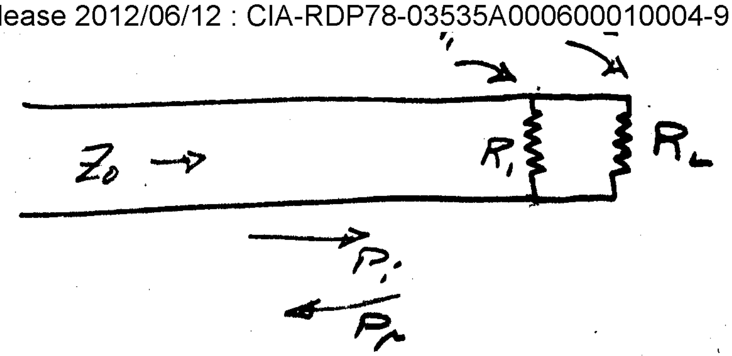
"MODIFIED" 1N26 CRYSTAL



IPC-46025



PIN for IPC # 45275



if $R = \dfrac{R_1 R_L}{R_1 + R_L}$

voltage refl. coeff $= \dfrac{R - Z_0}{R + Z_0}$ (1)

power " " $= \left(\dfrac{R - Z_0}{R + Z_0}\right)^2 = \dfrac{P_r}{P_i}$ (2)

also $P_1 R_1 = P_L R_L$
where $P_1 + P_L = P_i - P_r$ } or $P_i - P_r = P_L\left(1 + \dfrac{R_L}{R_1}\right)$ (3)

from (2) $\dfrac{P_i - P_r}{P_i} = 1 - \left(\dfrac{R - Z_0}{R + Z_0}\right)^2$ (4)

so (3) & (4) give:

$$\frac{P_L}{P_i} = \frac{1 - \left(\dfrac{R - Z_0}{R + Z_0}\right)^2}{1 + \dfrac{R_L}{R_1}} \qquad (5)$$

if $R = Z_0$

$$\boxed{\frac{P_L}{P_i} \doteq \frac{R_1}{R_1 + R_L}} = \frac{Z_0}{R_L}$$

compared with the case when $R_1 = \infty$

$$\frac{P_L}{P_i} = 1 - \left(\frac{R_L - Z_0}{R_L + Z_0}\right)^2 = \frac{(R_L + Z_0)^2 - (R_L - Z_0)^2}{(R_L + Z_0)^2}$$

$$\boxed{\frac{P_L}{P_i} = \frac{4 R_L Z_0}{(R_L + Z_0)^2}}$$

so that the reduction in absorbed power is:

$$F = \frac{4 R_L^2}{(R_L + Z_0)^2}$$

if $Z_0 = 100$, $R_L = 10\,000$ $\quad F \cong 4$

$R_L = 1\,000$ $\quad F = \frac{4}{1.21}$

$$\frac{\partial^{P_2/P_1}}{\partial R} = \left(\frac{1}{1+\frac{R_L}{R_1}}\right)(-2)\ \frac{(R+Z_0)-(R-Z_0)}{(R+Z_0)^2} + \left[1-\left(\frac{R-Z_0}{R+Z_0}\right)^2\right]\left(-\frac{R_L}{R_1^2}\right)\frac{\partial R_1}{\partial R}$$

$$R = \frac{R_1 R_L}{R_1+R_L}\ ; \qquad dR\,(R_1+R_L) + R\,dR_1 = R_L\,dR_1$$

$$\frac{dR_1}{dR} = \frac{R_1+R_L}{R_L-R}$$

So $$\frac{\partial}{\partial R} = -2\left(\frac{R_1}{R_1+R_L}\right)\frac{2Z_0}{(R+Z_0)^2} + \frac{(R+Z_0)^2-(R-Z_0)^2}{(R+Z_0)^2}\ \frac{R_L}{R_1^2}\ \frac{R_1+R_L}{R_L-R}$$

$$=0$$

$$-4\frac{R_1 Z_0}{(R_1+R_L)} = \overbrace{\left(\cancel{R^2}+2RZ_0+\cancel{Z_0^2}-\cancel{R_2}+2RZ_0-\cancel{Z_0^2}\right)}^{4RZ_0}\frac{R_L}{R_1^2}\ \frac{R_1+R_L}{R_L-R}$$

or $$\frac{-R_1}{R_1+R_L} = R\ \frac{R_L}{R_1^2}\ \frac{R_1+R_L}{R_L-R}$$

or $$-\frac{R_1^3}{(R_1+R_L)^2} = \frac{R R_L}{R_L-R}$$

or $$-\alpha\,(R_L-R) = R R_L$$

$$R(R_L-\alpha) = -\alpha R_L$$

$$R = \left(\frac{\alpha R_L}{\alpha-R_L}\right)$$

~~R=~~

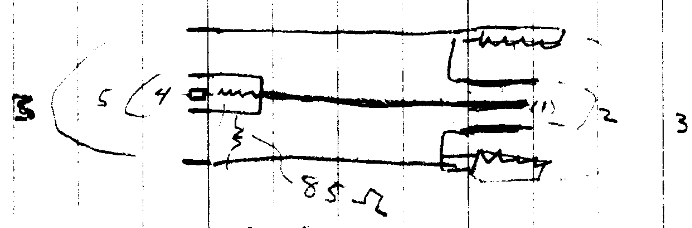
$$R = -\frac{R_1^3\, R_L}{(R_1+R_L)^2} \cdot \frac{1}{\dfrac{-R_1^3}{(R_1+R_L)^2} - \dfrac{R_L\,(R_1+R_L)^3}{(R_1+R_L^2)}}$$

$$= \frac{4\, R_1^3 R_L}{+R_1^3 + R_L(R_1+R_L)^2}$$

$$= \frac{R_1 R_L}{R_1 + R_L\left(\dfrac{R_1+R_L}{R_1}\right)^2}$$

1-2 - 85
2-4 - 160
2-5 - 85
1-4 - 75
5-3 85
1-3 85
2-3 0
1-5 0
3-4 160
4-5 75

1-2



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Temperature vs time
for constant voltage
Thermistor

ACS
1/15/56

Equations Related to Thermistor Temperature

Heat flow (calories/sec):

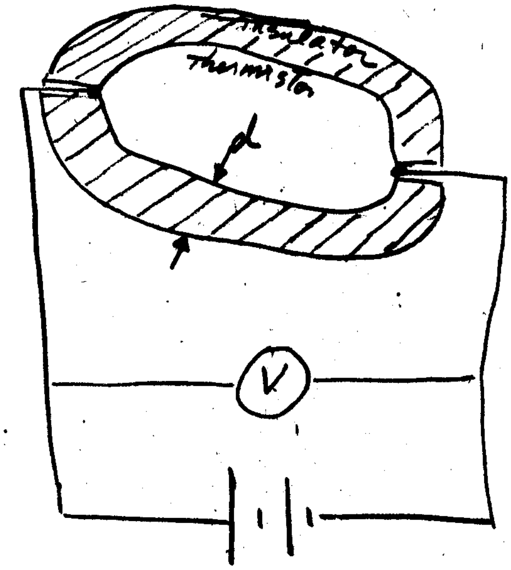
$$\frac{K(S_2+S_1)(T_1-T_2)}{2d}$$

Heat influx (calories/sec):

$$\frac{V^2}{4.85\,R(T)}$$

Heat radiation (calories/sec)

$$\frac{\sigma}{4.85} S_2 T_2^4$$



in general, $dT = \frac{1}{ms} dH$

thus:

$$M_1 s_1 \frac{dT_1}{dt} = \frac{V^2}{4.85R(T_1)} - \frac{K(S_2+S_1)(T_1-T_2)}{2d}$$

and

$$\frac{M_2 s_2}{2} \frac{d(T_1-T_2)}{dt} = \frac{K(S_2+S_1)(T_1-T_2)}{2d} - \frac{\sigma}{4.85} S_2 T_2^4$$

- if T_2 is of the order of the ambient temperature, the unit will also absorb radiation in appreciable quantity.

thermistor:

M_1 = mass
s_1 = specific heat
S_1 = surface area
V_1 = volume
ρ = specific gravity
T_1 = temperature (°K)

insulator:

M_2, s_2, S_2, etc

$\sigma = 5.710 \times 10^{-12}$ Joules / cm² sec (deg)

(Richtmeyer & Kennard, P. 183)

K = constant of thermal conductivity

T_2 = outside temp

$R(T)$ = resistance of thermistor

t = time - seconds

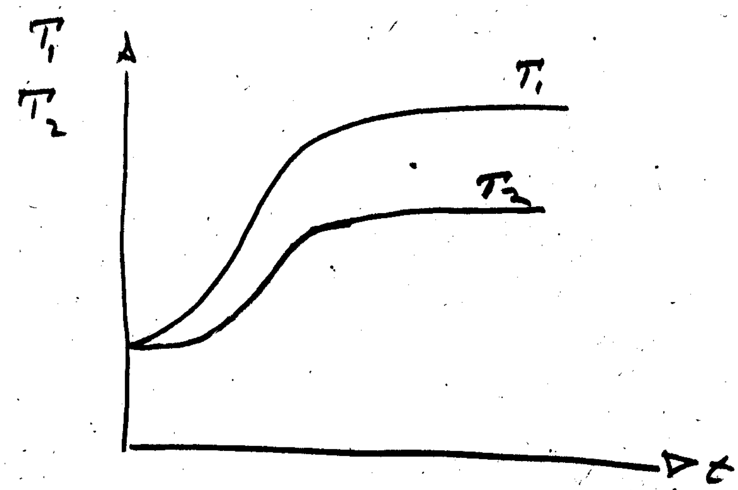
thus to make the thermistor heat quickly one would desire:

small mass (m_1)
small specific heat (s_1)
large voltage (V)
small thermistor resistance ($R(T)$)
small insulator conductivity (K)
small surface area (S_1)
large insulator thickness (d)

thus in general a ~~heat sensitive~~ timing thermistor should be small in size.
and the initial temperature rise would be

$$\left.\frac{dT_1}{dt}\right|_0 = \frac{V^2}{4.85\, m_1 s_1 R(T_1)}$$

; This rate would have a tendency to increase due to a decreasing $R(T)$ but to decrease because of an increasing $(T_1 - T_2)$ giving an "S" shaped curve.



25X1

$$P_r^{(1)} = \frac{P_T G_T G_R \lambda^2}{(4\pi)^2 R^2}$$

or $$\boxed{\frac{P_T}{4\pi R^2} = \frac{4\pi P_r}{G_T G_R \lambda^2}}$$

for 1N31, P_{max} for burnout is .1 → .5 watts (2)

suppose $G_T = G_R = 10$

and $\lambda^2 = (3\,cm)^2$

$= .01\,ft^2$

$\frac{4\pi}{900}(.1 \text{ to } .5)$ watts/cm²

then $\frac{P_T}{4\pi R^2} = 4\pi \times (.1 \text{ to } .5)$ watts/ft²

or the maximum incident intensity will be

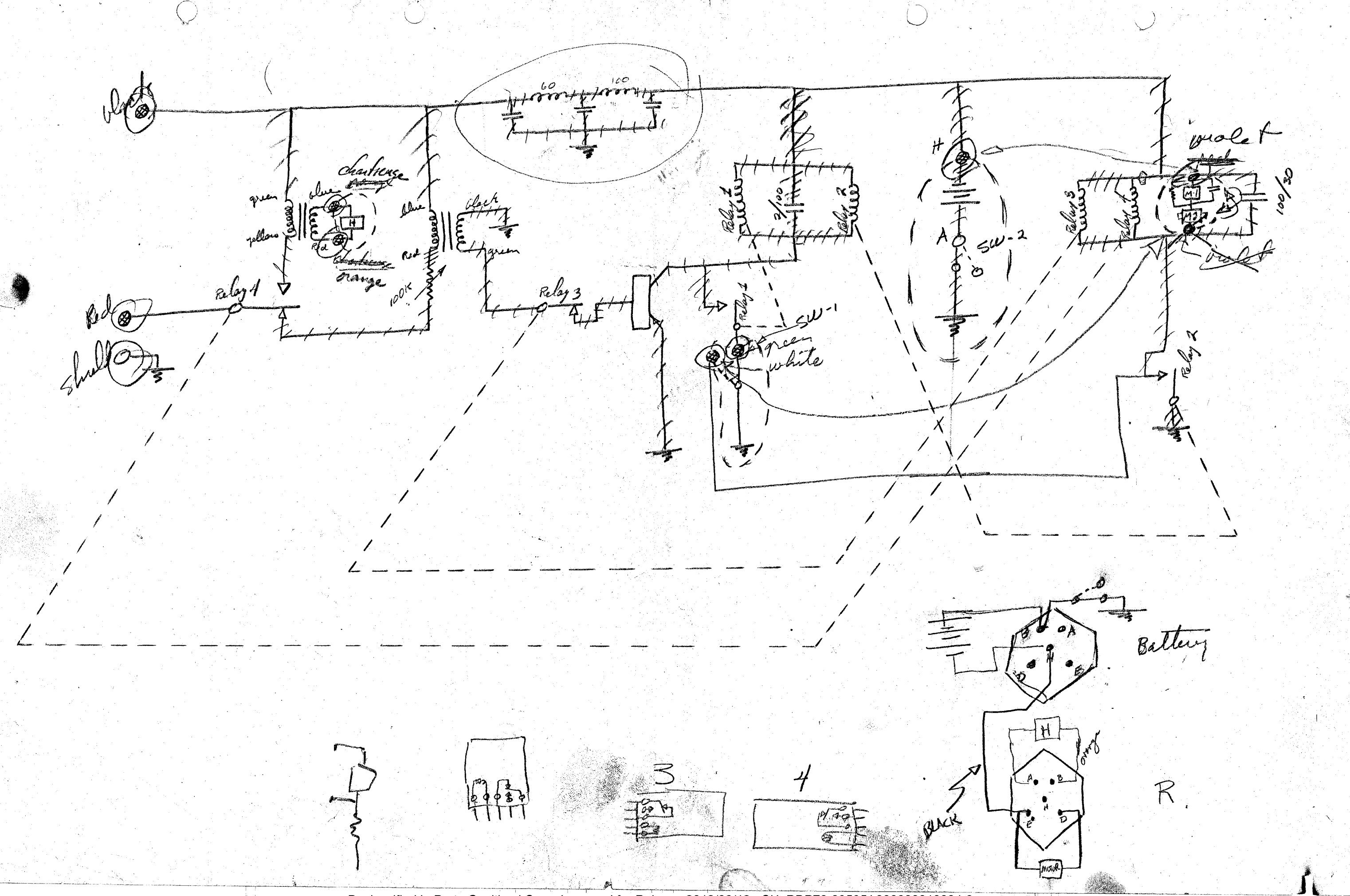
<u>.0014 to .007 watts/cm²</u>

and $\frac{P_T}{R^2} = 16$ to 80 watts/ft² gives the transmitted power in terms of range.

<u>for example</u> if R = 100 feet, P_T = <u>160 to 800 kw</u>

(1) P, 576 Silver, "Microwave antenna theory of design" Rad Lab #12

(2) P 263 Torrey & Whitmer, "Crystal Rectifiers", Rad Lab #15


60
100
green
yellow
blue
chartreuse
orange
blue
Red
100K
black
green
Relay 1
Relay 3
Red
Shield
Relay 1
Relay 2
SW-1
green
white
H
A
SW-2
Relay 3
Relay 1
violet
100/30
Relay 2
Battery
H
A
B
C
D
BLACK
3
4
R.

PARTS REQUIREMENT

5 Transformaers, 2,000-10,000 ohms, Argonne no AR-109 [redacted] STAT

5 Transformers, 400-20,000 ohms, Argonne no AR -105 COD 1 wk.

5 RF Chokes, 60 mh, 100 ma, Miller no 693 Available D.C.

5 RF Chakes, 150 Mh, 100 ma, Miller no 961 3-4 wks max.

10 Elgin "Neomite" NM2K relay, Coil res. 2000 ohms, sensitivity 100 mw ~~fast~~ Immediate

~~procurement was in excess of 180 days — phone call probably could shorten considerably~~

5 Haydon timing motor, series 9200, 6 volt, 70 ma, 1/5 rpm. Manufacturer 4 wks max.

Cap acitors: (Standard "Fansteel" items)

~~Tantalum~~

20 Tantalum, 10 mf at 25 volts

20 ~~175~~ Tantalum, 175 mf at 15 volts

15 Tantalum, 100 mf at 30 volts

7 Tantalum, 2 mf at 30 volts

Available D.C. 3-4 wks. max.

5 Transistors, 2N57, Minneapolis Honeywell

5 Potentiometers, 0-100,000 ohms

Available D.C. 3-4 wks max.

15 Transistors - 2N34, RCA?

Input Voltage Requirement: 10V p-p 5 mw. (3.5 V. RMS) 2000 Ω

Amp. 1/4 volt into 1/2 megohm.

Spare?

5 Microswitch levers, type JS-2

20 2N34', (transistors)

~~x~~
CONNECTORS 10 each

IPC #45275 (male)

IPC #46025 (female)

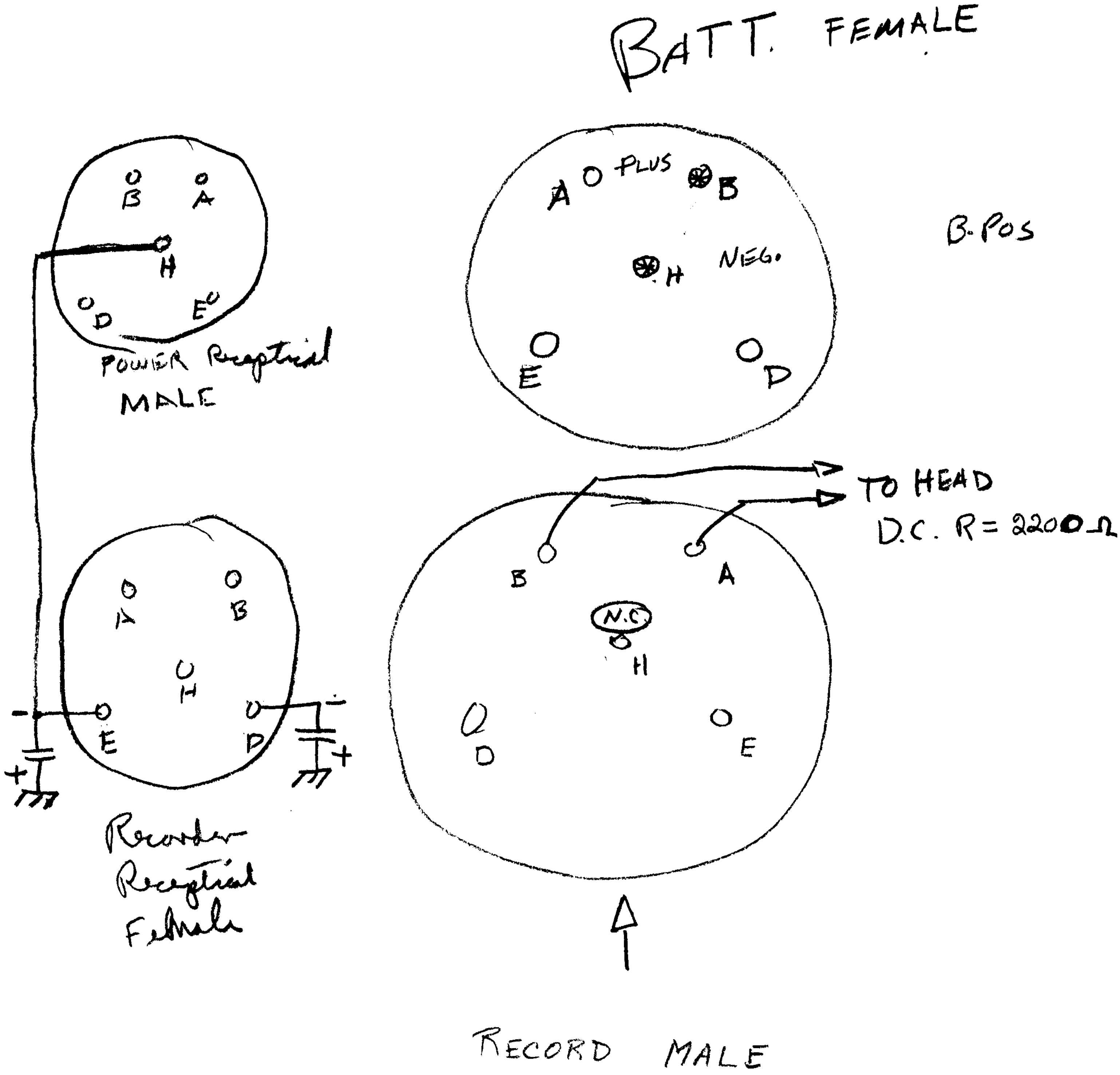
We have these on hand - should order more if we decide to use them.

* * *

BATTERIES

50 H R-1 Silver Cells

Some question whether these are required.



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Thermistor Time delay

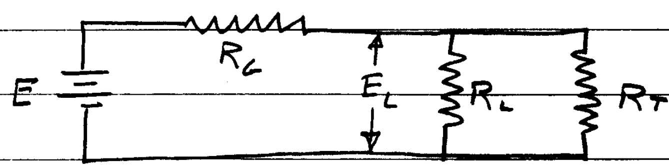
OCS

12 Jan 56

a Carborundum Co Type F, ~~—~~ thermistor may halfits resistance in the range from 20°C to 80°C

which means that a variation in R/R_1 may be about 8/5.

If the relay is to be timed with the following circuit:



R_G = Source resistance
R_L = load resistance
R_T = Thermistor resistance

$$\frac{E_L}{E} = \frac{R}{R_G + R} \qquad \text{where } R = \frac{R_L R_T}{R_L + R_T}$$

Thus it is seen that a larger negative resistance coefficient in R_T will allow the circuit to work ($\frac{E_L}{E}$ fall to a given fraction) for ~~—~~ smaller values of E and R_G.

The western Electric line of thermistors have a temp-coeff. of −4.4 %/°C compared to 2.2 %/°C for the Carborundum Company ones.

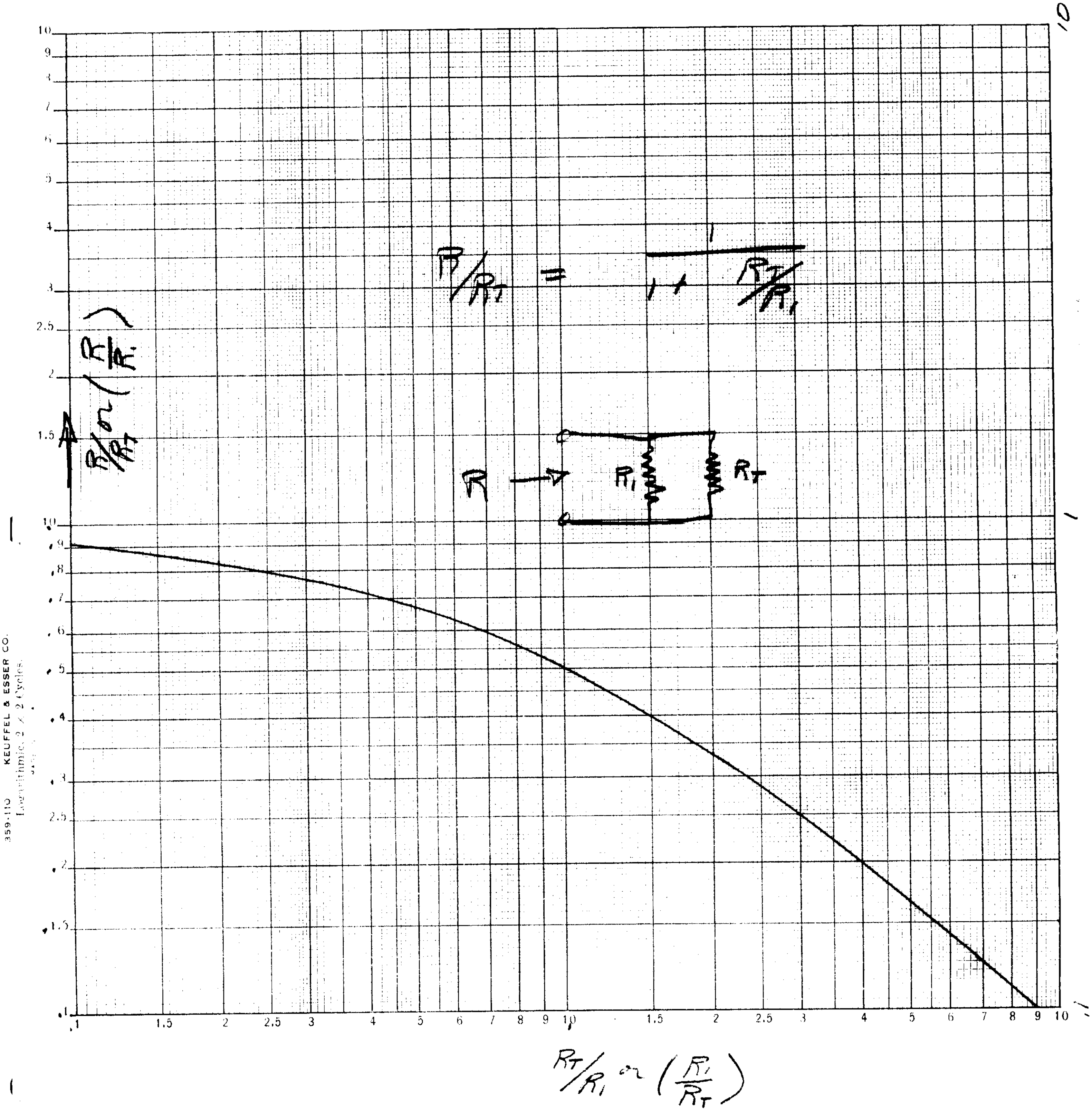
Thus six Western Electric 4A, 4B and ~~[illegible]~~ thermistors have been ordered.

Also previously ordered

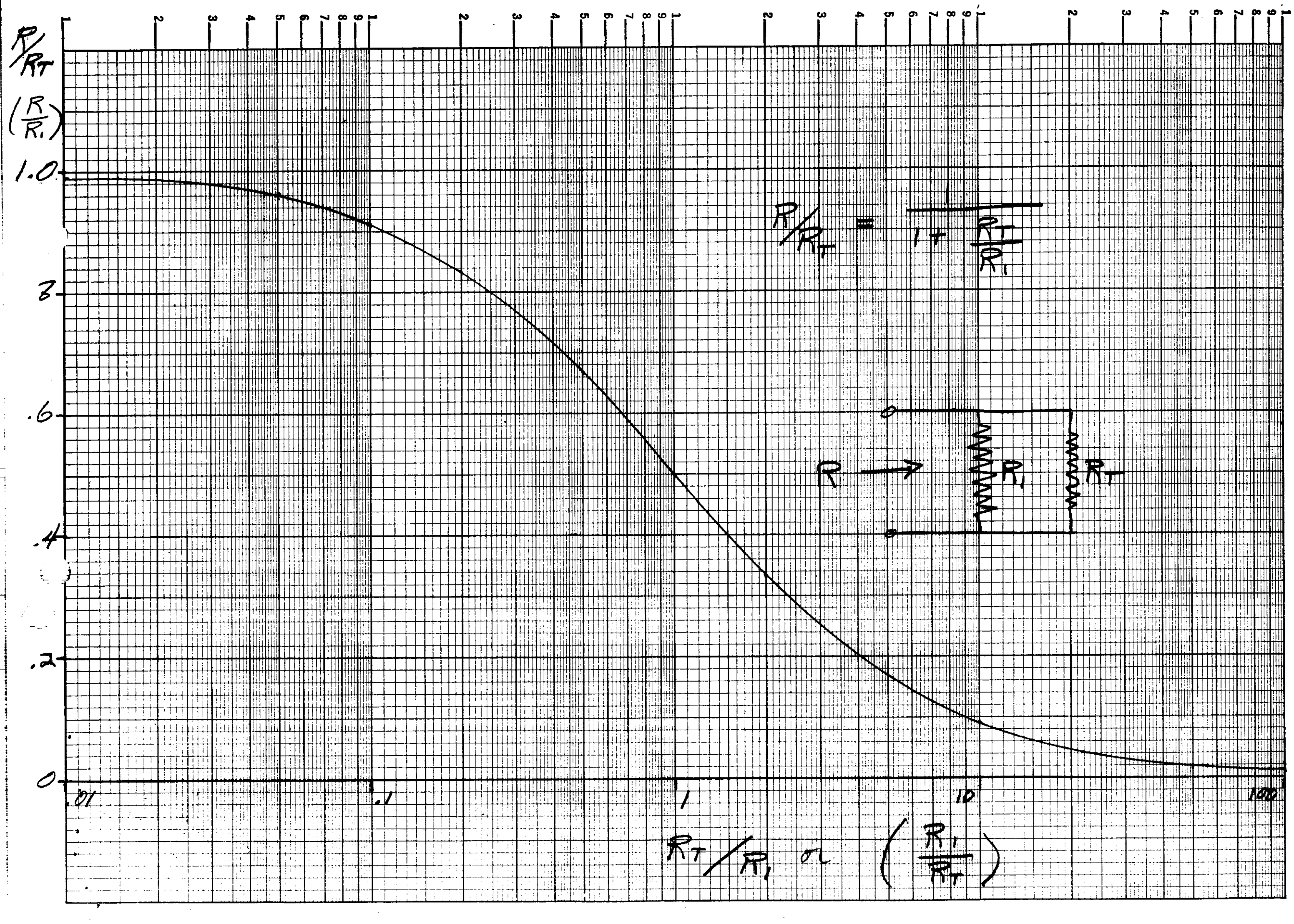
Type F thermistor kit #5

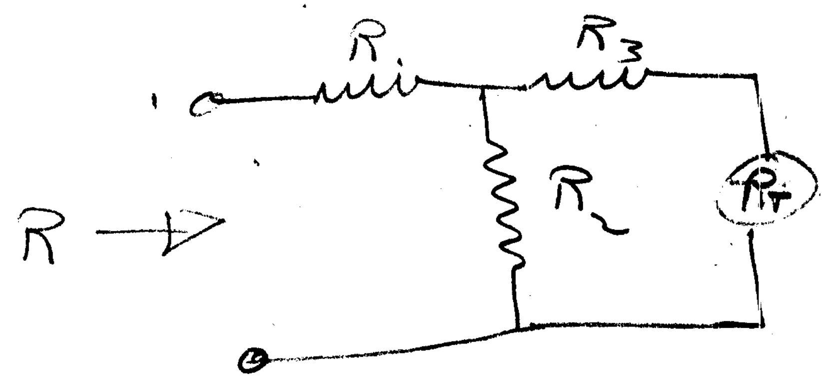
Carborundum Co
Niagara Falls, N.Y.

	R(25°C)	B	watts
1	5	1100	0.5
2	10	1400	0.5
3	20	1500	0.5
4	40	1450	0.25
5	220	1750	0.25
6	10,000	1950	0.25



R/R_T = 1 / (1 + R_T/R_1)
R
R_1
R_T
R/R_T or (R/R_1)
R_T/R_1 or (R_1/R_T)
359-110 KEUFFEL & ESSER CO.
Logarithmic 2 X 2 Cycles


R/RT
(R/R1)
1.0
.8
.6
.4
.2
0
.01
.1
1
10
100
R/RT = 1 / (1 + RT/R1)
R
R1
RT
RT/R1 or (R1/RT)



$$R = R_1 + \frac{1}{\frac{1}{R_2} + \frac{1}{R_3 + R_T}} \quad ; \quad R_T = R_0 \exp\left(B\left(\frac{1}{T} - \frac{1}{T_0}\right)\right)$$

when $T =$	50	0	-50
$R_T \simeq$	$\frac{R_0}{10}$	R_0	$10R_0$

$T = 0$

$$R = R_1 + \frac{1}{\frac{1}{R_2} + \frac{1}{R_3 + R_0}}$$

$T' = 50$

$$R' = R_1 + \frac{1}{\frac{1}{R_2} + \frac{1}{R_3 + \frac{R_0}{10}}}$$

$T'' = -50$

$$R'' = R_1 + \frac{1}{\frac{1}{R_2} + \frac{1}{R_3 + 10R_0}}$$

$$\frac{R}{R'} = \frac{\left(\frac{R_1}{R_2} + \frac{R_1}{R_3+R_0} + 1\right)}{\frac{1}{R_2} + \frac{1}{R_3+R_0}} \cdot \frac{\left(\frac{1}{R_2} + \frac{1}{R_3+\frac{R_0}{10}}\right)}{\left(\frac{R_1}{R_2} + \frac{R_1}{R_3+\frac{R_0}{10}} + 1\right)}$$

$$= \frac{\left[R_1(R_3+R_0) + R_1R_2 + R_2(R_3+R_0)\right]\left[R_2 + R_3 + \frac{R_0}{10}\right]}{\left[R_2+R_3+R_0\right]\left[R_1\left(R_3+\frac{R_0}{10}\right) + R_1R_2 + R_2\left(R_3+\frac{R_0}{10}\right)\right]}$$

$$= \frac{\left[R_1R_3 + R_1R_0 + R_1R_2 + R_2R_3 + R_2R_0\right]\left[R_2 + R_3 + \frac{R_0}{10}\right]}{\left[R_2+R_3+R_0\right]\left[R_1R_3 + \frac{R_1R_0}{10} + R_1R_2 + R_2R_3 + \frac{R_2R_0}{10}\right]}$$

$$= \frac{\begin{gathered}\left[R_1R_2R_3 + R_1R_2R_0 + R_1R_2^2 + R_2^2R_3 + R_2^2R_0 \\ + R_1R_3^2 + R_1R_3R_0 + R_1R_2R_3 + R_2R_3^2 + R_2R_3R_0 \\ + \frac{R_1R_3R_0}{10} + \frac{R_1R_0^2}{10} + \frac{R_1R_2R_0}{10} + \frac{R_2R_3R_0}{10} + \frac{R_2R_0^2}{10}\end{gathered}}{\begin{gathered}R_1R_2R_3 + \frac{R_1R_2R_0}{10} + R_1R_2^2 + R_2^2R_3 + \frac{R_2^2R_0}{10} \\ + R_1R_3^2 + \frac{R_1R_3R_0}{10} + R_1R_2R_3 + R_2R_3^2 + \frac{R_2R_3R_0}{10} \\ + R_1R_3R_0 + R_1R_0^2 + R_1R_2R_0 + R_2R_3R_0 + R_2R_0^2\end{gathered}}$$

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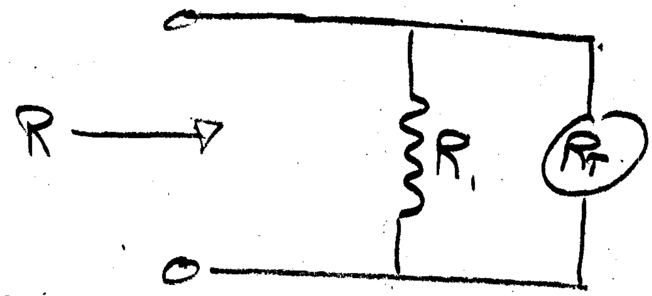
$$\Big[2R_1R_2R_3 + R_1R_2R_0 + R_1R_3R_0 + R_2R_3R_0 + R_1R_2^2 + R_2^2R_3 + R_1R_3^2 + R_2R_3^2 + \frac{R_1R_0^2}{10} + \frac{R_2R_0^2}{10} + \frac{R_1R_3R_0}{10} + \frac{R_2R_3R_0}{10} \cancel{+ R_2^2R_0} + \frac{R_1R_2R_0}{10} \Big] + R_2^2R_0$$

$$\Big[2R_1R_2R_3 + R_1R_2R_0 + R_1R_3R_0 + R_2R_3R_0 + R_1R_2^2 + R_2^2R_3 + R_1R_3^2 + R_2R_3^2 + \frac{R_1R_0^2}{10} + \frac{R_2R_0^2}{10} + \frac{R_1R_3R_0}{10} + \frac{R_2R_3R_0}{10} + \frac{R_1R_2R_0}{10} \Big] + \frac{R_2^2R_0}{10}$$

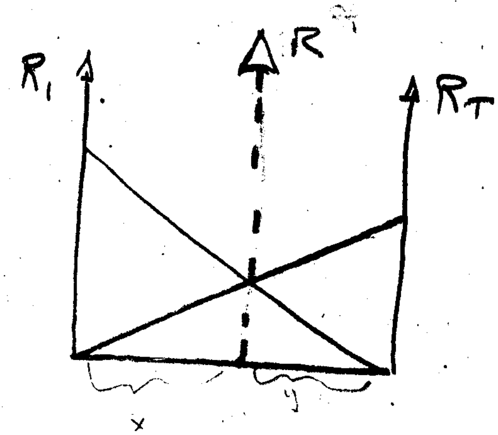
$$= \frac{\gamma + R_2^2R_0}{\gamma + \frac{R_2^2R_0}{10}}$$

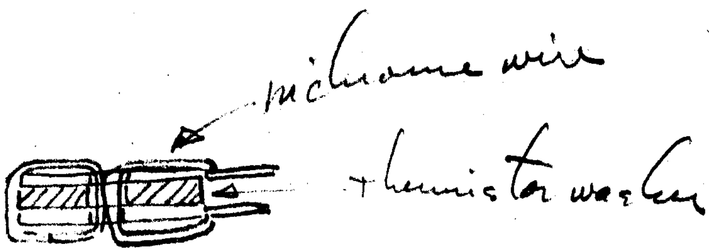
This means we want

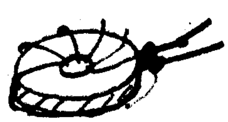
$\frac{R_2^2R_0}{\gamma}$ to be small.



$$R = \frac{R_1 R_T}{R_1 + R_T}$$







$$\left.\begin{aligned} \frac{x+y}{R_T} &= \frac{x}{R} \\ \frac{x+y}{R_1} &= \frac{y}{R} \end{aligned}\right\} \quad \frac{R_1}{R_T} = \frac{x}{y}$$

$$R = \frac{x}{x+y} R_T = \cancel{\frac{y}{x+y}} R_1$$

$$R = \frac{1}{1+\frac{y}{x}} R_T = \frac{R_T}{1+\frac{R_T}{R_1}}$$

$$= \frac{R_T R_1}{R_1 + R_T}$$

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